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The Effects of Laparoscopic Surgery and Nosocomial Infections on the Cost of Care: Evidence from Three Common Surgical Procedures

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ABSTRACT

Objective: To examine the cost of care for laparoscopic versus open surgery and the added cost of nosocomial infections for three common surgical procedures: cholecystectomy, hysterectomy, and appendectomy.
Methods: The Cardinal Health database repository was utilized to extract reimbursement data for laparoscopic and open cholecystectomy, hysterectomy, and appendectomy surgical procedures. Utilizing a 22-hospital sample and a Health Insurance Portability and Accountability Act compliant clinical data extraction technique, the Cardinal Health database repository produced a Nosocomial Infection Marker to identify and track nosocomial infection rates for these procedures. ICD-9 codes were utilized to identify 10,731 patients who had undergone these procedures between September 2004 and December 2006. Multivariable linear regression models were estimated to isolate the effects of laparoscopic versus open surgery and nosocomial infections on the cost of care.
Results: Laparoscopic surgery significantly reduces the overall cost of care for cholecystectomies, hysterectomies, and appendectomies. Controlling for the cost of nosocomial infection, incremental cost savings from laparoscopic versus open surgery for all three procedures average $1608. Cholecystectomy has the largest savings ($3299), followed by hysterectomy ($1385) and appendectomy ($1032). These cost savings in part reflect that patients undergoing laparoscopic procedures have shorter lengths of stay. In contrast, nosocomial infection increases costs substantially for each surgery type, raising costs for cholecystectomy by $4794, hysterectomy by $4528, and appendectomy by $6108.
Conclusion: The cost of care for laparoscopic surgery is lower than open surgery for cholecystectomy, hysterectomy, and appendectomy. This conclusion is based on actual hospital reimbursement data.
Keywords: laparoscopic appendectomy, laparoscopic cholecystectomy, laparoscopic hysterectomy, nosocomial infection, Nosocomial Infection Marker.

Introduction

For a variety of surgeries, the laparoscopic approach has been shown to involve less pain, shorter hospitalizations, improved cosmesis, and faster recovery times than open procedures [1–5]. In contrast, nosocomial infections have been associated with longer hospitalizations and slower recovery times [6–8]. However, the impact of both laparoscopic surgery and nosocomial infection on the cost of care has not been well delineated. This study seeks to quantify these relationships for three common surgical procedures: cholecystectomy, hysterectomy, and appendectomy.

The foundation of the study is a unique database constructed by a subsidiary of Cardinal Health (a major provider of healthcare industry services and products) that captures current reimbursement and provider experience with these surgical treatments while identifying associated nosocomial infections. This tool enables a more accurate cost assessment compared with previously published works that relied on charges, which often differ substantially from reimbursement, and data that are significantly older.

In evaluating the cost advantages of laparoscopic versus open surgery, it is acknowledged that the adoption rates of various laparoscopic procedures are quite variable. For example, by 1994 more than 85% of cholecystectomies were performed laparoscopically [9], a figure that may now be as high as 90% [10], making laparoscopic surgery the standard of care for that procedure [11,12]. For hysterectomies and appendectomies, however, the adoption rates have been much slower [13,14]. In the case of hysterectomy, the relatively slow adoption of laparoscopic technique is somewhat surprising given that prospective randomized clinical trials have demonstrated that total laparoscopic hysterectomy and laparoscopically assisted vaginal hysterectomies for benign diseases involve less postoperative pain and blood loss, fewer transfusions, and faster recovery times, with complication rates similar to that of abdominal hysterectomy [15]. In contrast to the profile of laparoscopic hysterectomy, the clinical advantages of laparoscopic versus open appendectomy remain controversial. There is currently no consensus as to whether laparoscopy or open surgery should be the routine choice for acute appendicitis.

In addition to the clinical advantages of reduced pain and faster recovery times, there is now evidence that infection rates following laparoscopic surgery are lower than those for open surgery. In a recent study utilizing the Cardinal Health database, laparoscopic cholecystectomy and hysterectomy were shown to each reduce the overall odds of acquiring nosocomial infections by more than 50% ($P < 0.01$). Laparoscopic cholecystectomy and hysterectomy also resulted in statistically significantly fewer readmissions with nosocomial infections ($P < 0.01$) [16].

In surgical patients overall, rates of nosocomial infection have been reported to range from 1.9% to 25.4%, depending upon the procedure [17], and often add significantly to the costs of health care. To date, however, there is relatively little information quantifying the effects of nosocomial infections on the cost of care for specific surgical procedures.

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Costs of Care for Laparoscopic Surgery

A review of the literature suggests that the economic impact of laparoscopic surgery in comparison with open procedures remains inconclusive. In the case of cholecystectomy, for example, some studies report that laparoscopic surgery increased costs for hospitalization [18–21], while others have reached the opposite conclusion [22–31]. Still other studies have found no significant differences in costs associated with laparoscopic versus open surgery [32,33]. One study determined that laparoscopic cholecystectomy initially cost more than open procedures, but that costs declined once physicians gained sufficient experience with the procedure [34].

Most studies comparing the costs of laparoscopic with open hysterectomy have concluded that laparoscopic surgery is more costly [35–43], although several report little or no difference in cost [44–47]. Results appear most divergent for appendectomy. While many studies conclude that laparoscopic appendectomy is more costly [47–57], others report little or no difference [58–65], or a cost advantage for laparoscopic appendectomy [66–70].

In addition to obtaining inconclusive results, the cost literature on laparoscopic cholecystectomy, hysterectomy, and appendectomy has largely employed charge data, which may differ substantially from the actual amount reimbursed to the hospital. For example, the charges that a hospital submits for payment generally exceed the amount actually paid to the hospital, sometimes substantially so. This renders results using charge data less relevant from both payer and provider perspectives. Moreover, previous studies typically employed smaller sample sizes than the present analysis and may have lacked sufficient power to detect some differences. Finally, earlier work in this area examined data that are at least 10 years old. Such data reflect neither current reimbursement practices nor the level of familiarity with laparoscopic procedures among contemporary physicians.

Costs of Care for Nosocomial Infection

A number of studies have attempted to quantify the costs of nosocomial infections [6–8,71–81]. While estimates vary, nosocomial infections have been found to raise hospitalization costs substantially, often ranging from several thousand dollars to more than 10 thousand. Typically, previous cost estimates of nosocomial infection have focused on the intensive care unit, or have assessed nosocomial infection costs throughout the hospital. Studies that have examined nosocomial infection costs for specific surgeries generally explore the costs of surgical site infections only. Our analysis explores the cost implications of the broader measure of nosocomial infection as it includes infections coming from more than just the surgical site in patients undergoing cholecystectomy, hysterectomy, or appendectomy.

Methods

Data

We utilized a unique database that includes reimbursement information that is updated daily. Hence, it captures the latest reimbursement practices and provider experience with laparoscopic and open procedures.

Data were obtained and analyzed by a Cardinal Health subsidiary, which identifies, monitors and tracks nosocomial infection rates for hospitals. The subsidiary company houses data from 10.3 million admissions from US hospitals in 28 states and 2.7 million admissions including corresponding financial data. Using ICD-9 procedure codes supplied by hospitals, patients having undergone open and laparoscopic cholecystectomy, hysterectomy, or appendectomy procedures were identified to determine the effects of laparoscopic versus open procedures on the costs of care for these three surgeries. In this database, the costs of care are measured as the actual payments received from payers for each procedure and thus are costs from the payer perspective.

Financial data are obtained annually from client hospitals as a part of the Nosocomial Infection Marker (NIM) Surveillance Service. The clinical and financial data are aggregated into a single database allowing for analysis of clinical and financial outcomes studies. The data utilized in this analysis were collected between September 1, 2004 and December 31, 2006 from 22 hospitals in 15 states. The hospitals were primarily tertiary non-major trauma hospitals. These hospitals had a median number of 359 beds, with an interquartile range from 191 to 483 beds; one hospital exceeded 1000 beds and two had fewer than 150.

Only those subjects undergoing cholecystectomy, hysterectomy, or appendectomy were extracted from the database. Primary ICD-9 procedure codes were used to identify both procedure and type of surgery (laparoscopic vs. open). Including only patients with a primary ICD-9 procedure code for one of the three surgical modalities ensures that the surgery was the main procedure performed and the reason for the patient visit. The data also included information on subject's age, gender, insurance status (Medicaid, Medicare, private, other), indicators of the hospital in which the surgery occurred, and NIM.

Identifying Nosocomial Infections

The company utilized a clinical data extraction technique that is secure, Health Insurance Portability and Accountability Act compliant and electronic to acquire the data from the hospital sample. Cardinal Health receives encrypted clinical feeds from the client hospitals' Laboratory, Admission Discharge and Transfer, and Census systems that are normalized and processed utilizing proprietary technology to produce an NIM. The NIM was proven to be an effective and accurate identifier of nosocomial infections in a study by Brossette et al. [82], which also described the process by which nosocomial infections are identified. The NIM was defined as "a patient specimen with a nonduplicate hospital isolate, where a specimen is a collection of material obtained from a single source (e.g., blood, urine, sputum, or wound). A *nonduplicate hospital isolate* is a nonduplicate isolate obtained from a specimen collected on or after hospital day 3 or within 14 days of hospital discharge (within 30 days of discharge for surgical wound specimens)." [82]

Statistical Analyses

Two types of multivariable regression models were estimated to isolate the effects of laparoscopic versus open surgery and nosocomial infections on the payment received by the hospital for providing care. The first revenue model pools all three surgical procedures and includes binary indicators to adjust costs for the influence of each procedure. The second model provides individual revenue estimates for each surgical procedure: cholecystectomy, hysterectomy, and appendectomy.

The first cost model may be written as:

$$\begin{aligned} \mathrm{COST} = {} & \alpha_0 + \alpha_1\mathrm{LAP} + \alpha_2\mathrm{NIM} + \alpha_3\mathrm{CHOLECYS} + \\ & \alpha_4\mathrm{HYST} + \boldsymbol{\theta}\mathbf{X} + \varepsilon, \end{aligned} \tag{1}$$

where:

COST = payment received for the surgical procedure;

LAP = binary variable (BV) equal to 1 if the procedure was laparoscopic and 0 if open;

NIM = BV equal to 1 if subject incurred a nosocomial infection and 0 otherwise;
CHOLECYS = BV equal to 1 if surgery was cholecys tectomy and 0 otherwise;
HYST = BV equal to 1 if surgery was hysterectomy and 0 otherwise;
X = a vector of patient, insurance, and hospital level variables that affect costs;
α_0–α_4,$\boldsymbol{\theta}$ = coefficients to be estimated; and
ε = an error term

Reimbursement amounts are right-skewed. To address this issue, we estimate Generalized Linear Model (GLM) gamma models. These models have been shown to be more efficient relative to alternative approaches such as semi-log models [83]. The individual effects of cholecystectomy and hysterectomy on costs are measured relative to appendectomy, which serves as the reference group. The vector **X** includes patient's age and gender, insurance status (Medicaid, Medicare, private, or other), and a series of binary variables that adjust for hospital-specific effects on cost of care. The key coefficients of interest are α_1, which measures the effect of laparoscopic versus open surgery on costs, and α_2, which quantifies the effects of nosocomial infections on cost of care. Similar cost equations are estimated separately for each procedure. These equations include all of the variables in Equation (1) above, with the exception of indicators of surgery type.

To gain further insight into how laparoscopic versus open surgeries and nosocomial infections may affect costs, we also estimate equations predicting hospital length of stay. It is important to note that length of stay is not included in the cost models because it is endogenous and would potentially introduce multicollinearity problems as well.

$$\mathrm{LOS} = \beta_0 + \beta_1\mathrm{LAP} + \beta_2\mathrm{NIM} + \beta_3\mathrm{CHOLECYS} + \beta_4\mathrm{HYST} + \boldsymbol{\psi}\mathbf{X} + \mu, \tag{2}$$

where:

LOS = length of stay in the hospital; and other vari ables are as described above.

As with cost of care, length of stay models are estimated for the pooled sample as in Equation (2), and separately for each surgical modality using GLM gamma models.

Results

The names, descriptions, and summary statistics for the variables used in this analysis are provided in Table 1. The mean age of subjects included in our study is 47.4 years. A large number of hysterectomies are included in our sample, resulting in males representing only 24% of the sample. More than 20% of the subjects are insured by Medicare and 7% are insured by Medicaid. Nosocomial infections occurred in 3% of patients, and 60% of surgeries were performed laparoscopically.

The rates for laparoscopic surgery and nosocomial infection varied by surgery type. For cholecystectomy, the rate of laparoscopic surgery was 84%; the corresponding figures for hysterectomy and appendectomy were 40% and 65%, respectively. Nosocomial infections rates were 3.6% for cholecystectomies, 2.5% for hysterectomies, and 2.3% for appendectomies.

Table 1 Names and descriptions of study variables (N = 10,731)

Variable name	Description	Mean	Standard deviation
Cost	Payment received for treatment	8,212.91	7,001.42
Length of Stay	Length of stay	3.48	3.34
Lap	Binary variable (BV) = 1 if subject received laparoscopic surgery and 0 if open surgery	0.60	0.49
Nosocomial Infection Marker	BV = 1 if subject incurred nosocomial infection else = 0	0.03	0.17
Cholecystectomy*	BV = 1 if subject received cholecystectomy else = 0	0.32	0.47
Hysterectomy*	BV = 1 if subject received hysterectomy else = 0	0.45	0.50
Age	Subject's age in years	47.38	18.22
Male	BV = 1 if subject is male else = 0	0.24	0.43
Medicaid†	BV = 1 if subject is insured by Medicaid else = 0	0.07	0.26
Medicare†	BV = 1 if subject is insured by Medicare else = 0	0.21	0.41
Other Insurance in Tables†	BV = 1 if subject is insured by other carrier else = 0	0.10	0.30
Hospital 2‡	BV = 1 if surgery performed at hospital 2 else = 0	0.04	0.19
Hospital 3‡	BV = 1 if surgery performed at hospital 3 else = 0	0.24	0.42
Hospital 4‡	BV = 1 if surgery performed at hospital 4 else = 0	0.02	0.13
Hospital 5‡	BV = 1 if surgery performed at hospital 5 else = 0	0.05	0.21
Hospital 6‡	BV = 1 if surgery performed at hospital 6 else = 0	0.06	0.24
Hospital 7‡	BV = 1 if surgery performed at hospital 7 else = 0	0.03	0.16
Hospital 8‡	BV = 1 if surgery performed at hospital 8 else = 0	0.05	0.22
Hospital 9‡	BV = 1 if surgery performed at hospital 9 else = 0	0.05	0.21
Hospital 10‡	BV = 1 if surgery performed at hospital 10 else = 0	0.03	0.16
Hospital 11‡	BV = 1 if surgery performed at hospital 11 else = 0	0.04	0.19
Hospital 12‡	BV = 1 if surgery performed at hospital 12 else = 0	0.06	0.23
Hospital 13‡	BV = 1 if surgery performed at hospital 13 else = 0	0.04	0.19
Hospital 14‡	BV = 1 if surgery performed at hospital 14 else = 0	0.03	0.16
Hospital 15	BV = 1 if surgery performed at hospital 15 else = 0	0.07	0.25
Hospital 16‡	BV = 1 if surgery performed at hospital 16 else = 0	0.02	0.14
Hospital 17‡	BV = 1 if surgery performed at hospital 17 else = 0	0.01	0.09
Hospital 18‡	BV = 1 if surgery performed at hospital 18 else = 0	0.03	0.17
Hospital 19‡	BV = 1 if surgery performed at hospital 19 else = 0	0.03	0.18
Hospital 20‡	BV = 1 if surgery performed at hospital 20 else = 0	0.02	0.14
Hospital 21‡	BV = 1 if surgery performed at hospital 21 else = 0	0.05	0.21
Hospital 22‡	BV = 1 if surgery performed at hospital 22 else = 0	0.01	0.10

*Appendectomy is the reference group.
†Private insurance is the reference group.
‡Hospital 1 is the reference group.

Table 2 Multivariate cost estimates: overall and by individual procedures (GLM gamma estimates with log link): dependent variable: revenue

Variable	All N = 10,731 LR test = 3,486	Cholecystectomy N = 3,473 LR test = 1,041	Hysterectomy N = 4,783 LR test = 1,246	Appendectomy N = 2,475 LR test = 1,084
Intercept	8.60†	8.91*	8.34†	8.31†
Lap	−0.20†	−0.32†	−0.20†	−0.13†
Nosocomial Infection Marker	0.63†	0.47†	0.66†	0.76†
Cholecystectomy	0.22†		—	—
Hysterectomy	−0.21†		—	—
Age	0.01†	0.005†	0.01†	0.01†
Male	0.04*	0.07†	—	−0.004
Medicaid	−0.42†	−0.43†	−0.31†	−0.59†
Medicare	−0.11†	−0.13†	−0.11†	0.05
Other Insurance in Tables	−0.05†	−0.08*	0.05	−0.19†
Hospital 2	0.13†	0.30†	0.06	−0.07
Hospital 3	0.46†	0.49†	0.42†	0.30†
Hospital 4	0.46†	0.63†	0.26†	0.29†
Hospital 5	−0.19†	0.01	−0.19†	−0.67†
Hospital 6	0.41†	0.54†	0.35†	0.15
Hospital 7	−0.17†	0.07	−0.29†	−0.52†
Hospital 8	0.01	0.08	0.19†	−0.38†
Hospital 9	0.23†	0.36†	0.26†	−0.18
Hospital 10	−0.31†	0.02	−0.38†	−0.57†
Hospital 11	0.45†	0.50†	0.47†	0.19
Hospital 12	0.67†	0.62†	0.70†	0.49†
Hospital 13	0.37†	0.63†	0.21†	0.09
Hospital 14	0.21†	0.43†	0.19†	−0.12
Hospital 15	0.10†	0.16†	0.16†	−0.24†
Hospital 16	0.11*	0.24†	0.09	−0.10
Hospital 17	0.22	0.28†	0.22*	−0.03
Hospital 18	−0.32†	−0.01	−0.46†	−0.68†
Hospital 19	0.06	0.19†	−0.03	−0.04
Hospital 20	0.27†	0.28†	0.34†	0.18
Hospital 21	0.35†	0.40†	0.29†	0.26*
Hospital 22	0.21†	0.28†	0.09	0.10

*Statistically significant at the 5% level, two-tailed test.
†Statistically significant at the 1% level, two-tailed test.
Hospital 1 is the reference hospital.
GLM, Generalized Linear Model; LR test, likelihood ratio test.

Cost of Care Estimates

Table 2 reports the multivariable cost of care estimates for the overall sample and separate estimates for each surgical procedure. As the table indicates, laparoscopic surgery significantly reduces costs in the overall sample and for all three surgical procedures individually.

For all three procedures, nosocomial infection has a direct and highly significant impact on increasing the cost of care. Costs increase with age and are higher for males. In comparison with private insurance, the reference cohort, subjects insured by Medicaid have lower costs. This reflects the fact that in most states, Medicaid pays at a rate of approximately 33% of commercial insurers. Cost of care tends to be lower for Medicare patients, possibly reflecting lower reimbursement rates under Medicare relative to privately insured individuals who constitute the reference cohort. The results also reveal that costs vary substantially across the hospitals examined in this study. Finally, the full sample results indicate that the cost of care is highest for cholecystectomies.

To gain a sense of the degree to which laparoscopic surgery and nosocomial infections affect reimbursement, we computed incremental costs using the equation estimates reported in Table 2. These incremental costs are evaluated at sample means. The results, provided in Table 3, reveal that the cost savings from laparoscopic surgery are substantial. The overall sample indicates that laparoscopic surgery reduces costs by $1608. The cost reduction is even greater for cholecystectomies—$3299. In contrast, nosocomial infection has a large positive impact on costs for all three procedures, increasing costs the most for appendectomies, ($6108) followed by cholecystectomies ($4794) and hysterectomies ($4528).

Effects on Length of Stay

To better understand the source of these cost differences, multivariable estimates of length of stay are reported in Table 4. In every case, laparoscopic surgery significantly reduces length of stay and nosocomial infection extends it. Length of stay is longer for older patients and for males. Medicare patients have longer

Table 3 Estimated incremental effects of laparoscopic surgery and nosocomial infection on costs ($); overall and by individual procedure

Variable	All	Cholecystectomy	Hysterectomy	Appendectomy
Lap	−1608*	−3299*	−1385*	−1032*
Nosocomial Infection Marker	5182*	4794*	4528*	6108*

*Statistically significant at the 1% level, two-tailed test.

Table 4 Multivariate length of stay estimates: overall and by individual procedures (GLM gamma estimates with log link): dependent variable: length of stay

Variable	All N = 10,731; LR test = 3,676	Cholecystectomy N = 3,473; LR test = 1,496	Hysterectomy N = 4,783; LR test = 1,002	Appendectomy N = 2,475; LR test = 1,048
Intercept	0.94†	1.03†	0.82†	1.23†
Lap	–0.45†	–0.38†	–0.53†	–0.39†
Nosocomial Infection Marker	0.91†	0.88†	0.91†	0.98†
Cholecystectomy	0.38†	—	—	—
Hysterectomy	–0.25†	—	—	—
Age	0.01†	0.01†	0.01†	0.01†
Male	0.04†	0.07		0.01
Medicaid	0.17†	0.13†	0.23†	0.15†
Medicare	0.18†	0.13†	0.18†	0.40†
Other Insurance in Tables	0.08†	0.05	0.02	0.14†
Hospital 2	–0.08*	0.21	–0.18†	–0.47†
Hospital 3	0.15†	0.44†	–0.03	–0.17*
Hospital 4	0.01	0.29†	–0.22†	–0.25*
Hospital 5	0.03	0.26†	–0.04	–0.50†
Hospital 6	0.07*	0.42†	–0.09*	–0.43†
Hospital 7	–0.18†	0.19*	–0.38†	–0.56†
Hospital 8	0.14†	0.23†	0.25†	–0.18
Hospital 9	–0.21†	0.05	–0.23†	–0.63†
Hospital 10	0.01	0.24*	–0.08*	–0.26*
Hospital 11	0.18†	0.40†	–0.05	–0.10
Hospital 12	0.04	0.10	0.09*	–0.40†
Hospital 13	0.01	0.37†	–0.18†	–0.34†
Hospital 14	–0.10*	0.27†	–0.29†	–0.41†
Hospital 15	–0.10†	–0.05*	–0.13†	–0.27†
Hospital 16	–0.18†	0.09	–0.19†	–0.63†
Hospital 17	0.15*	0.01	–0.10	–0.56†
Hospital 18	0.14†	0.37†	0.06	–0.19
Hospital 19	0.15†	0.31†	0.05	–0.10
Hospital 20	–0.05	0.18†	–0.0001	–0.48†
Hospital 21	–0.16†	0.19*	–0.34†	–0.26*
Hospital 22	0.04	0.16	–0.25†	0.01

*Statistically significant at the 5% level, two-tailed test.
†Statistically significant at the 1% level, two-tailed test.
Hospital 1 is the reference hospital.
GLM, Generalized Linear Model; LR test, likelihood ratio test.

lengths of stay as well, which is consistent with the notion that this older patient group has more difficult recovery periods from these procedures. We find substantial variation in length of stay across hospitals.

As with the cost of care estimates, we computed incremental effects of laparoscopic surgery and nosocomial infection on length of stay for the three procedures. These results, presented in Table 5, indicate that overall, laparoscopic procedures reduce average length of stay by 1.58 days while nosocomial infections increase length of stay by 3.16 days.

Discussion

Cholecystectomies, appendectomies, and hysterectomies are common surgeries with known benefits to patients in need of these procedures. In many cases, laparoscopic surgery is a safe and effective alternative to open cholecystectomies, appendectomies, or hysterectomies [1–5]. The present study finds that the cost implications of laparoscopic surgery appear favorable as compared with open surgery for the each of three surgical procedures examined.

The analysis makes several contributions to understanding the costs associated with these three surgeries. First and most significantly, we examine more current data comparing the cost of laparoscopic versus open procedures. Evidence suggests that as physicians gain experience with laparoscopic procedures, the cost of care associated with these procedures declines [84]. Using more current data—when physicians tend to have gained more experience using laparoscopic procedures—our study shows that laparoscopic surgery lowers costs significantly for all three surgical procedures examined. Second, we use actual amounts paid by the insurer rather than the charge data typically employed in previous studies. This provides a better sense of the economic burden of these procedures on third-party payers. Third, we examine cholecystectomy, hysterectomy, and appendectomy using a consistent sample drawn from the same group of hospitals. This helps mitigate sources of heterogeneity stemming from different time periods and treatment locations. Such heterogeneity makes it more difficult to draw comparisons across these procedures. Fourth, our sample sizes compare favorably with most previous cost studies of these procedures, and help to ensure that we have sufficient statistical power to detect mean-

Table 5 Estimated incremental effects of laparoscopic surgery and nosocomial infection on LOS: overall and by individual procedure

Variable	All	Cholecystectomy	Hysterectomy	Appendectomy
Lap	–1.58*	–1.84*	–1.46*	–1.16*
Nosocomial Infection Marker	3.16*	4.29*	2.52*	2.90*

*Statistically significant at the 1% level, two-tailed test.

ingful differences where they exist. Finally, our study utilizes a unique database that tracks nosocomial infections, allowing us to quantify the large economic burden when such infections occur following these procedures, whether open or laparoscopic.

Further Cost Advantages of Laparoscopic Surgery

There is evidence to suggest that our estimated effects of laparoscopic surgery on the cost of care are conservative. Our models adjust for nosocomial infection, but studies have found that laparoscopic surgery is protective against these infections, reducing the rate of these infections by 50% or more [85]. If so, an additional cost saving from laparoscopic surgery would result from reductions in the incidence of nosocomial infections, potentially reducing those costs by at least 50% or more.

Limitations

There are some limitations to our data and analyses that must be recognized. First, although we have a large number of patients, our sample comes from 22 hospitals. While these hospitals vary considerably in size and geographic location, they may not be representative of hospitals nationally so the findings may not be generalizable to particular hospitals or settings. Second, while we controlled for a number of potential confounders, there may be other important factors for which we were unable to adjust. For example, we were unable to identify if surgeries were performed on an emergent or elective basis. As the vast majority of appendectomies are emergent while most hysterectomies are elective, failure to include this potential confounder likely introduced little bias into these estimates. In contrast, cholecystectomies are generally performed both emergently and electively and it would have been desirable to control for this.

Conclusion

Our analysis finds that laparoscopic surgery reduces the cost of care substantially for cholecystectomy, hysterectomy, and appendectomy. Laparoscopic surgery also reduces length of stay significantly for each procedure. Although the merit of laparoscopic surgery for appendectomy is currently less conclusive than for the other two procedures, we find that it leads to significantly lower costs and reduced length of stay for this procedure as well. As others have argued, laparoscopic appendectomy surgery may be an attractive alternative to the open procedure given that it confers benefits valued by patients, such as reduced hospitals stays and fewer complication rates [86].

As providers gain experience with laparoscopic procedures, it would be useful to update cost of care estimates to determine if this greater experience leads to efficiency gains in terms of lower costs. Another important direction for future research is to perform comparative cost of care analyses for other procedures such as colectomy for which laparoscopic approaches are becoming more popular.

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